International Journal of Mechanical and Production Engineering Research and Development (IJMPERD)
ISSN(P): 2249-6890; ISSN(E): 2249-8001
Vol. 8, Issue 3, Jun 2018, 81-88

EXPERIMENTAL INVESTIGATION ON STIR CAST ALUMINIUM WITH ALUMINIUM OXIDE POWDERS

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ABSTRACT

Aluminium MMC's are chosen over other conventional materials in aeronautics, automobiles and in oceanic areas because of their enhanced abilities such as high strength to weight ratio, stiffness, corrosion resisting nature, and tribological properties. The stir casting technique is one of the promising and economical routes for producing Al MMC's. Literature shows that only Aluminium alloys were reinforced with Aluminium Oxide (Al_2O_3), SiC, Graphite but pure Aluminium was not used with the only alumina. The composite under study contains Aluminium as Matrix element and alumina as reinforcement. The Aluminium is stirring cast and in the molten Al, 5wt% and 10wt% of Aluminium Oxide powders are added. The obtained composite castings are tested for Hardness using the Vickers Hardness Tester. The results of pure Aluminium and that of composites are compared. A hardness of 90% Al&10%Al_2O_3 composite is higher than the rest of the samples. The microstructure of these samples is studied and obtained using the Advanced microscope image analyzer. Wear test is also performed using the pin- on-disc tribometer for tribological details like Wear, Frictional Force, Coefficient Of Friction and respective graphs are also plotted for further study.

KEYWORDS: Aluminium Metal Matrix Composites, Stir Casting, Wear Test, Hardness & Microstructural Study

Received: Mar 15, 2018; **Accepted:** Apr 05, 2018; **Published:** Apr 25, 2018; **Paper Id.:** IJMPERDJUN20189

Original Article

1. INTRODUCTION

For doing research and conducting experiments on Composites, the first and foremost step is knowing about the types of the composites and among them, Metal Matrix composites (MMCs) are very prominent. A composite is a material comprising of two or more elements. The elements are microscopically bonded and aren't dispersible in each other. In General, a composite comprises of reinforcement lodged inside a matrix (metals, polymers) which grips it for getting the required geometry while the reinforcement enhances the strength of the matrix. When fabricated precisely, the newly formed blend displays improved strength over individual elements. The tribological properties and hardness play a greater role in choosing the metal matrix composites for utilizing in multiple applications.[1]

Rajendra S. K and Ramesha C. M in [1] have worked on Al7075 Metal Matrix Composites and used Al2O3 and SiC as reinforcements. For the fabrication of these composites, they used Metallurgy Vortex and powder metallurgy routes and they found that usage of these reinforcements in Al7075 improved it's mechanical as well as tribological properties. There are many advanced fabrication methods for MMCs like stir casting, squeeze casting,

etc. Among them, stir casting technique is a cost-effective technique also called as 'vortex method'. It is mostly chosen owing to its accessibility, less cost of making, flexibility. For the work done on Al2219-TiC particulate composites, liquid casting route was used and TiC reinforcement was added in the percentages of 2wt%, 4wt%and 6wt% to the Al2219 alloy. Usage of the reinforcement enhanced it's density compared to the matrix Al2219. Ultimate tensile Strength of the composite increased to a greater extent on an addition of Tic in different proportions and the increase was to the tune of 6%, 21% and 48% for 3 proportions respectively. Yield Strength was also identified to have got increased very much upon addition of Tic[2]. The most used methods for fabrication of hybrid A. M. C'S are stir casting and powder metallurgy methods. Hence, there is a great requirement to study more to utilize the advantages of the newly made friction stir prepared AMCs and bulk AMCs [3]. The AMCs developed using AA7075 reinforced with B4C, Al2O3, SiC had improvement in mechanical properties when tested for hardness and tensile studies. B4C particles embedded in AA7075 matrix exhibited high results over the rest owing to its high internal bonds. [4].

Tony Thomas. A et al. in [5] performed work on Aluminium metal matrix composites to decide the best stirring and feeder mechanisms, they modified the existing feeder mechanism and identified improved results. They showed that percentage of elongation increased by 34% Buckling load also got enhanced by 5.41%, Brinell's hardness number also increased by about 31%. Stir casing method may be used very well to fabricate AMC's with less density with improved mechanical properties also. This process is economically over the conventional route for making composites. Isotropic Materials are fabricated effectively. Usage of Magnesium enhances wettability. Stirrer Design decides the flow trend of melt [6]. The aluminum alloy of Cu-Zn-Mg combination as a matrix and Alumina as reinforcement prepared by casting route is identified to be effective. The authors found that up to 10% addition of alumina improves the tensile strength of the alloy and value is 297 MPa and elongation improvement of 17%. Cu with 2.7% improves the strength and ductile nature in addition to Mg, Zn in the matrix. Increase in Al2O3 content in the matrix improves porosity of composite. [7].

Rajeshkumar Gangaram Bhandare and Parshuram M. Sonawane in [8] have identified that PAMC samples weighed lower than parent matrix Al6061 owing to it's less denser graphite and porosity. Graphite acting as a dry surface lubricant, decreased the c. o. f value between a composite pin and rotating steel disc by 11%. The smallest value identified for c. o. f is 0.31 for Al6061+ (2.50% Al2O3 + 5%SiC + 6% Graphite) composite. SiC reduces the rate of wear. Adding SiC and Al2O3 improves UTS. For Al 6061+ (2.5%Al2O3 + 5.0%SiC + 4.0% Graphite) composite, highest tensile strength obtained is 154.1 N/mm2 which increased by 28.0%. The composites having 6061Al with 6%, 9% and 12wt% of Al2O3 as reinforcement were fabricated by melting stirring route after the reinforcing particles were preheated. The microstructure images show a uniform distribution of Al2O3 in the 6061Al matrix. Hardness got improved with a rise in wt% of alumina. Tensile and yield strengths were higher for composites, whereas ductility was lesser than that of cast 6061Al. Increase in wt% of alumina, increased tensile strength gradually. [9].

Al 6061 composite reinforced with Silicon Carbide and Graphite was prepared well-using stir casting method by altering wt% of Gr from 3% to 9% and keeping wt% of constant at 6%. From the results obtained authors concluded that the Hardness of made composites is more than that of the base AL6061 matrix. 6wt% of Silicon Carbide improves hardness very well, but adding Gr though reduces hardness showed value more than base alloy. Reduction in hardness of Al 6061 composite is may be because of poor wettability of Gr by base matrix. Adding 6.0% Silicon Carbide and Graphite from 3.0% to 9.0% enhances the tensile strength than that of matrix Al6061[10]. Al 7075 matrix composites having reinforcements SiC and Al2O3 showed good mechanical properties over the composites either SiC or alumina only.

A hardness of composite a rises because of the rise in SiC particles[12].

Therefore, literature provided above shows that no work has been done before on pure Al reinforced with only Al2O3 and mostly Al alloys were considered for research using a combination of reinforcements like Al2O3, SiC, Graphite, Gr etc. So, the present work aims at providing an idea about the Al-Al2O3 composite in terms of mechanical and tribological abilities substantiated by the microstructural study.

2. EXPERIMENTATION

2.1. Materials Used

For the metal matrix composite, the base matrix selected is pure Aluminium obtained in the form of ingots and the reinforcement chosen is Al_2O_3 of the size 50-60 microns. The detailed composition of the composite is, as mentioned in table1.

Table 1: Chemical Constitution of Al-Al_2O_3 Composites

S. No	Composition	Wt%
1	Pure Aluminium	100%
2	Aluminium+Al_2O_3	95%+5%
3	Aluminium+Al_2O_3	90%+10%

2.2. Composite Preparation

The metal matrix composite has been fabricated by the most economical method Known as “Stir Casting”. In the current work, Pure Al ingot is taken as the matrix material and Al_2O_3 as reinforcement. At first, the casting of pure Al is made. For that, the required pure aluminium ingot of 1kg is measured and put in the graphite crucible present in a Muffle Furnace. The temperature of the furnace is set at 700^0C controlled by Digital Temperature Controller. After reaching that temperature, the molten Al obtained is poured in a cylindrical shaped Cast Iron mold of size 150 mm x 18 mm diameter and then after a few minutes the mold is unfastened and the solidified Al castings are taken out. Now, the Al ingot is placed in a graphite crucible at a temperature of 750^0C for composite (95% Al+5% Al_2O_3) preparation and the reinforcement Al_2O_3 added is 5wt% in the vortex generated by mechanical stirring supported by a variable speed motor. The stirring is proceeded to get a uniform combination of two contents in the slurry. The stirrer speed is adjusted using speed controller and r. p. m is 350. The rotation is maintained for about 3 mins. To maintain inertness, Argon is used at 5 bar pressure. Then after that, the molten composite is transferred to the required cylindrical mold. The casting solidifies in 5 mins. After that, the castings for 90 %Al and 10% Al_2O_3 are prepared using the same procedure and the temperature of the furnace is set at 800^0C.

Figure 1: Equipment Used for Stir Casting and Castings Obtained in the Mould

2.3. Testing

For knowing the hardness of the Al-Al_2O_3 composites, the specimens prepared are tested under Vickers hardness tester. The castings obtained are cut according to required dimensions i.e 10mm x 16mm diameter on a lathe machine. The cut samples are properly filed and polished using emery sheets of grades 1/0,2/0,3/0 and4/0 until the mirror finish is obtained. After that the specimens are disc polished on disc polishing machine using graphite water as a coolant for rotating mukamal clothed disc. The polished samples are etched using Keller's reagent and then the samples are placed on the table of the vicker's tester. After seeing the microstructure of samples, the load of 1 kg for a dwell time of 10 sec is applied to the specimen**.** Then from the indentation formed the hardness value is identified. The hardness has been found for pure as well as for both 5% and 10% composites. For examining the microstructure, the samples were polished using 4 grades of emery papers and then they are disc polished and then microstructure of the samples was identified using Advanced Inverted Metallurgical Microscope fitted with Image Analyzer with 200X magnification. The tribological properties of these samples were also found out by performing Wear Test using "Ducom" Pin-On-Disc Tribometer. The wear samples were prepared as per ASTM G99 standards and results are obtained on a computer.

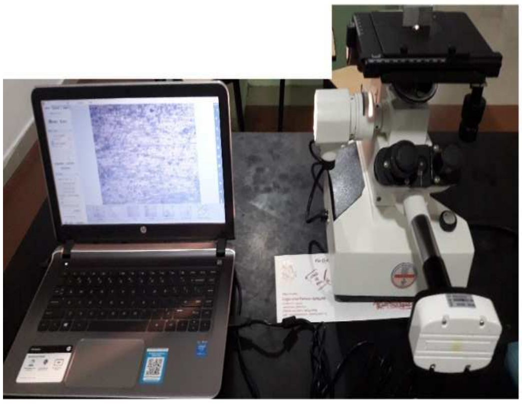


Figure 2: Vicker's Hardness Tester **Figure 3: Inverted Microscope Fitted with Image**

Analyzer and Computer for Microstructure.

Figure 4: Pin On Disc Tribometer

3. RESULTS AND DISCUSSIONS

3.1 Hardness Test

The hardness test performed on the prepared samples using Vickers hardness tester yielded following results :

Table 2: Hardness Values of Specimens

S. No	Composition	Hardness (VPN)
1	Pure Aluminium	26.3
2	95%Al & 5 %Al_2O_3	31.63
3	90%Al & 10%Al_2O_3	33.48

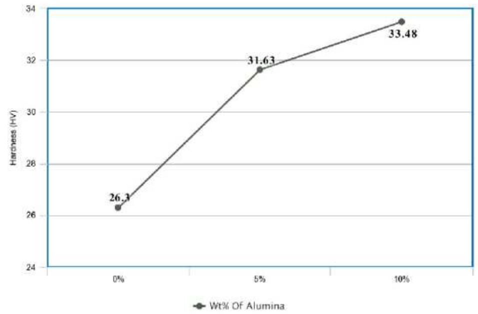


Figure 5: Variation in Hardness of Al with Al_2O_3 before and After Addition

From the above Figure 3, it is evident that the hardness of the composite increased after pure Al was added 5wt. % and 10 wt.% of Al_2O_3 particulates. The graph shows a steep rise in the value and from this, we can notice that increase in wt% of reinforcement in the base matrix enhances its mechanical strength.

3.2 Wear Test

Wear rate is identified to be rising with the rise in load and sliding distance. Percentage of wear lessens at higher speeds over lower speeds of the steel disc. Adding Sic reduces noise as well as vibration while in motion. SiC also reduces c. o. f while in motion. Composite possessing high wt% of reinforcement has the least wear rate at every sliding distance. The interfacial strength and the shape of reinforcement will increase the wear-resisting ability at higher sliding distances[11].

The wear test was performed on the specimens of size 35mm X 8mm diameter pins which were machined and polished on CNC Lathe Machine in order to get the good surface finish so that pins can be in good contact with the steel disc. The wear test yielded results such as Wear (microns), Frictional Force(N) and Coefficient Of Friction for all three samples and respective graphs are also plotted. The test parameters for all three samples are loaded : 30N speed: 716 rpm, time=11min, track diameter:80 mm, Sliding Velocity:2000 m/s, Sliding Distance:2000 m.

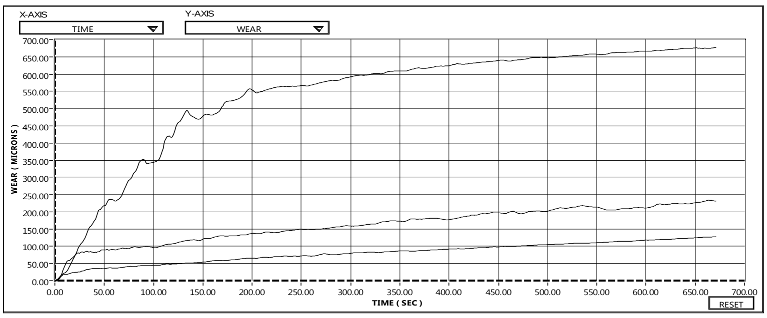


Figure 6: Wear Vs Time Graphs of 3 Samples
(Pure Al, 95%Al&5%Al_2O_3 and 90%Al &10% Al_2O_3)

Inference: Therefore, from Figure 6, it is clear that as a time of rotation of disc increases, wear of the material also increases and from above Figure we can say that, pure al has the high amount of wear than the rest of the composites.

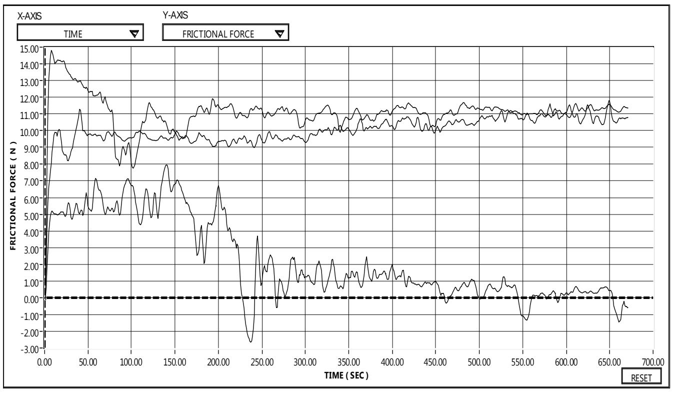


Figure 7: Frictional Force Vs Time Graphs of 3 Samples (Pure Al, 95%Al&5%Al_2O_3 and 90%Al &10% Al_2O_3)

Inference: From Figure 6, we can infer that as time increases, frictional force does not remain constant and keeps changing. The reason for this is due to non-uniform wear of the samples affected by the distribution of particles inside the sample. Wear for pure Al is higher and slightly similar to 5wt% composite.

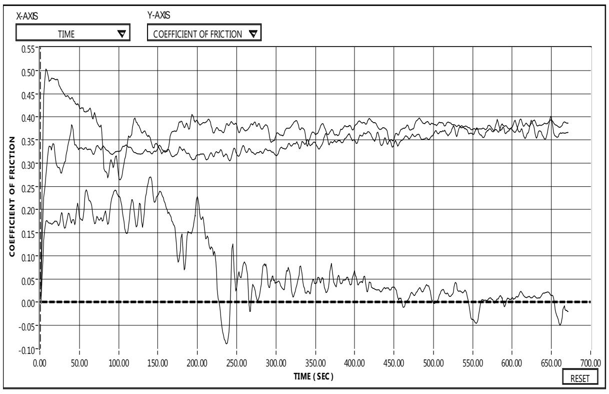
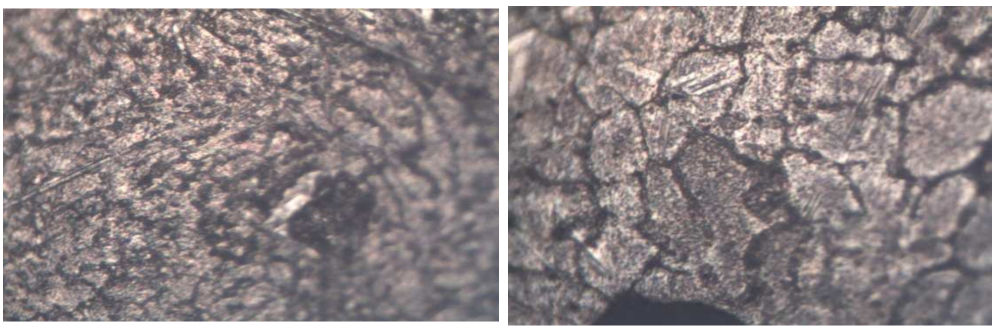


Figure 8 Coefficient Of Friction Vs Time Graphs of 3 Samples (Pure Al, 95%Al&5%Al_2O_3 and 90%Al &10% Al_2O_3)

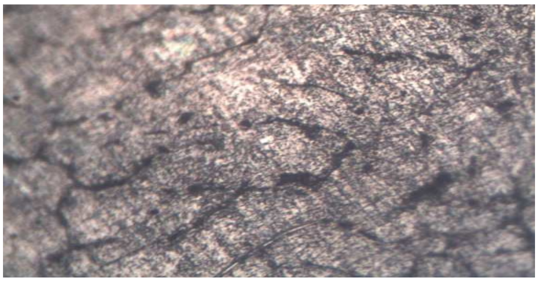
Inference: From Figure 8, we can infer that coefficient of friction is high for pure Al over other composites and with the rise in wt% of reinforcement, c. o. f reduces.

3.3 Microstructural Details

The Microstructures of the three samples performed at 200X Magnification are given below in Figure 9:(a-c)



(a) Microstructure of Pure Aluminium at 200X (b) Microstructure of 95%Al &5%Al_2O_3 at 200 X



(c) Microstructure of 90% Al &10%Al_2O_3 at 200X

4. CONCLUSIONS

From the details provided in the above sections, the conclusions drawn are, using the Stir Casting Method, the metal matrix composites have been successfully fabricated. Using Vickers hardness tester, hardness of 3 samples has been found out and from graphs provided above it is evident that composite with 10wt% of Al2O3 has higher hardness relatively. An increase in the amount of reinforcement in the base matrix is found to be improving the mechanical properties of the whole composite. For studying tribological properties such as Wear, Frictional Force, Coefficient of Friction, wear test has been conducted for constant sliding velocity, sliding distance and constant load. From the graphs of wear test, we can infer that as reinforcement increases, wear of the composite decreases and coefficient of Friction is also less for composites over the base matrix. Wear Resistance of the composites increases with reinforcement. From micrographs, we can notice the symmetrical division of Al2O3 particles throughout the surface and composite surface appears denser with an increase in wt% of reinforcement. The vortex formed while the stirrer is running, eliminates dendrites because of high frictional interaction between particles and Al matrix, and induces uniform distribution.

ACKNOWLEDGEMENTS

The authors are thankful to Dr. J. Siva Rama Krishna, Department of Physics, Acharya Nagarjuna University for giving reference to carry out experimental work at A. N. U, Dr. M. Gopi Krishna, H. O. D, Department of Mechanical Engineering, A. N. U and technicians there for granting permission to use Stir Casting equipment and Vickers Hardness Tester, Dr. T. Babu Rao, Department of Mechanical Engineering, Koneru Lakshmaih Educational Foundation for providing Wear Test Equipment and technicians at both Metallurgy and Manufacturing laboratories at K. L. E. F.

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